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Quarterly Report for January - June, 1993
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A) Objectives:

Algorithm-development activities by our group involve modeling coastal Case II Waters and deriving algorithms based upon those models. Since AVIRIS data are used to simulate the future MODIS-N and SeaWiFS sensors, development of a method to calibrate the AVIRIS data and to apply atmospheric corrections to the data is one of our current primary objectives. We also have collected field data for algorithm development.

B) Accomplishments:

1): The following cruises, one of them accompanied with an AVIRIS overflight have been accomplished and data from the experiments are being reduced and evaluated at the present time:

a. An R/V Bartlett cruise was made from the Mississippi River plume to the West Florida shelf from April 5 to 18, 1993. Partitioning of the absorption coefficients of water samples and collecting remote sensing reflectance data were carried out on this cruise. Pigment and in-water optical measurements were made by cruise collaborators.

b. An AVIRIS overflight on June 5, 1993, accompanied a cruise that covered both the Mississippi river plume and the West Florida shelf near Tampa Bay, FL. Activities similar to the above were carried out on this campaign.

2): We have been looking into algorithms for bathymetry using AVIRIS data and field measurements along transects from the Florida
Straits into Biscayne Bay of South Florida taken after Hurricane Andrew. We have used remote sensing reflectance calculations from AVIRIS data to estimate bottom depths (M. K. Hamilton et al., 1993) and compared the results with bathymetric charts. In the process we found that possibly Hurricane Andrew has filled the southern part of Card Sound, south of Biscayne Bay, with sediments eroded from the uplands north west of the Turkey Point power plant of Florida Power and Light. The infilling appears to be as much as 7' to 8' of sediment.

3): Extension of the Carder et al., 1991, reflectance algorithms to describe remote-sensing reflectance has resulted in a Case II SeaWiFS/MODIS algorithm for [Chl a] and CDOC that has been tested on the west Florida shelf and the results were reported at the May SeaWiFS algorithm development workshop in Maryland. The algorithm parameterization was developed on the basis of representative spectral shapes for the west Florida shelf of specific absorption curves for phytoplankton, detritus and gelbstoff.

4): Models have been developed for use with hyperspectral remote-sensing reflectance data collected just above the air-sea interface for the West Florida Shelf[1,2,3,4,5]. They respond to variations in pigment, detrital, and gelbstoff absorption, chlorophyll a and gelbstoff fluorescence, water Raman scattering, backscattering by water and particulate, and bottom depth and albedo. To date these models have not been systematically used to interpret hyperspectral data derived from high-altitude airborne sensors, which can provide a wide variation in component contributions in a single scene.

The water-leaving radiance values collected on a windy day near the mouth of Tampa Bay by AVIRIS on March 15, 1990, were very bright, with maximum remote-sensing reflectance R_{rs} values (the ratio of the water-leaving radiance to the downwelling irradiance) of about 0.035 $ster^{-1}$, even for the deep ship channels. In general, maximum R_{rs} values (L_w/E_d) for open ocean stations range from about 0.005 to 0.01 $ster^{-1}$. The high R_{rs} values for the Bay at the time of the study suggest that the bottom depth was very shallow or the water was very turbid due to the high winds and tidal currents. This enigma was better understood by modeling the R_{rs} spectra.

According to Kirk's as well as Morel and Gentili's Monte Carlo simulations, the popular simple expression, $R \approx 0.33 b_b/a$, relating sub-surface irradiance reflectance (R) to the ratio of the back-scattering coefficient (b_b) to absorption coefficient (a), is not valid for $b_b/a > 0.25$. This means that it may no longer be valid for values of remote-sensing reflectance (above-surface ratio of water-leaving radiance to downwelling irradiance) where $R_{rs} > 0.01$. Since there has been no simple R_{rs} expression developed for very turbid waters, we developed one based in part on Monte Carlo simulations and empirical adjustments to an R_{rs} model. We then applied it to rather turbid coastal waters near Tampa Bay to evaluate its utility for unmixing the optical components affecting the water-leaving radiance. With the high spectral (10nm) and spatial (20m) resolution of AVIRIS data, the water depth and bottom type were deduced using the model for shallow waters. Bottom types included sand, grass flats, and emergent vegetation, with a variety of levels of wave and current-induced suspended sediments apparent in the imagery. It also included turbid water in a deep ship channel that had been scoured off an adjacent shoal region, creating the appearance of a "false" bottom at about 1.5m. The results were presented at the SPIE meeting on the 14th of April in Orlando, FL and have been submitted to SPIE for publication.

5): A method has been developed which permits estimation of the spectral light field at depth through measurements of photosynthetically available radiation (*PAR*) and phytoplankton absorption (a_{ph}) and by sampling of the surface optical properties. The spectral light field can then be used to calculate the photosynthetically usable radiation (*PUR*) and pigment-harvested radiation (*PHR*). With the value of *PHR* and measured primary production at depth, the quantum yield (ϕ) for primary production at depth was calculated. For cloudy days the quantum yield curve as a function of PHR was $\phi = 0.069 * e^{-2.68(PUR)}$. Production of the low-light-adapted phytoplankton appeared to be severely reduced due to photo-inhibition for a sunny-day observation. The effects on *PUR* and *PHR* due to variations in the gelbstoff concentration and the color of incident irradiance are also addressed. This method was presented at the Marine Light-Mixed Layers Culmination Workshop on the 14th of June in Rhode Island. It is titled "A Simple Method for Estimating Photons Absorbed at Depth by Phytoplankton".

6): While we use and have reported a vicarious calibration method for AVIRIS (Carder et al, 1993), we need to know how stable AVIRIS is from scene-to-scene over a long flight. An atmospheric-correction method is under development that uses cloud-shadowed pixels together with pixels in a neighboring region of similar optical properties, called the cloud-shadow method. This method uses cloud-shadowed pixels in combination with pixels in a neighboring region of similar optical properties to remove atmospheric effects from ocean scenes. These neighboring pixels can then be used as known reflectance targets for validation of the sensor calibration and atmospheric correction. The method uses the difference between water-leaving radiance values for these two regions. This allows nearly identical optical contributions to the two signals (e.g. path radiance and Fresnel-reflected skylight) to be removed, leaving mostly solar photons backscattered from beneath the sea to dominate the residual signal. Normalization by incident solar irradiance reaching the sea surface provides the remote-sensing reflectance of the ocean at the location of the neighbor region.

Errors result from this method if corrections are not made for the following: 1) reduction of the path radiance over the shadowed pixels resulting from partial shadowing of the overlying atmospheric column; and 2) adjacency effects resulting from solar-derived photons leaving the water from the bright, surrounding waters that are scattered into the field of view for the shadowed pixels.

The results for a scene seaward of Key Biscayne, Florida are shown in Figure 1, where results are normalized by the incoming solar irradiance ${}_{sol}E_d$ (no skylight) to form remote-sensing reflectance spectra. Note that the spectrum resulting from the cloud-shadow method differs from that using conventional atmospheric correction methodology (see Carder et al., 1993) by only about 3.5%. This derived reflectance spectrum can in principle serve as a calibrated ground target to help with model parameterization for atmospheric correction of the entire scene, or in validation of the calibration of a sensor for scenes where conventional methods were unavailable. We are fine tuning this method by using a Monte Carlo method to evaluate pixel-adjacency effects for differing atmospheres and cloud geometries. This method was presented at the Workshop on Atmospheric Correction of Landsat Imagery, Torrance, CA on June 29 to July 1, 1993. It was titled "Satellite-Sensor Calibration Using The Cloud-Shadow

Method".

C): Anticipated Activities:

Reduction of data and its assimilation into models for Case II algorithm development for gelbstoff and chlorophyll concentrations on subtropical shelves will continue based largely on our newly acquired data sets. Algorithms for tying the package effect to chlorophyll concentrations are being developed as well, for use in Case I waters. Continued efforts to publish our results have a high priority for the next six months.

References

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